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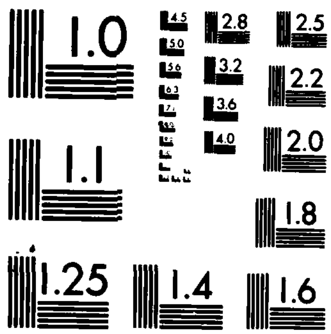

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We automated a visual physiology experiment that formerly was performed manually. The control of a light stimulus was synchronized with the collection of nerve cell response from kitten visual cortex, using Digital Equipment Corporation's MINC. The computer was integrated into several aspects of the experiment, ranging from data manipulation, storage and histogramming, to the control of the stimulus sweep, orientation, speed, and duration. The computer also directed nerve spike output to a screen, a printer and a floppy disc memory.

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AUTOMATIC CONTROL OF A

VISUAL PHYSIOLOGY EXPERIMENT,

USING MINC

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January 1984

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OFFICE OF NAVAL RESEARCH
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ABSTRACT

We automated a visual physiology experiment that formerly was performed manually. The control of a light stimulus was synchronized with the collection of nerve cell response from kitten visual cortex, using Digital Equipment Corporation's MINC. The computer was integrated into several aspects of the experiment, ranging from data manipulation, storage, and histogramming, to the control of the stimulus <u>sweep</u>, <u>orientation</u>, <u>speed</u>, and <u>duration</u>. The computer also directed nerve spike output to a screen, a printer and a floppy disc memory.

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INTRODUCTION

Our lab, like several others around the world, studies kitten visual cortex neurons by allowing the experimenter to listen to nerve cell spikes while manually controlling a visual stimulus on a screen in front of the animal. Recently we have acquired a MINC laboratory controller, and have begun automating the study of these cells.

The current automation project involved two major aspects: hardware and software.

Hardware: An external memory buffer circuit was designed to enhance real time processing capability and to ease the computer's manipulation of nerve cell data. The circuit is capable of functioning in two modes: Mode I collects data for sweeps of duration under one second; each sweep is separated into one millisecond (ms.) duration bins. Mode II collects data for sweeps between one and twenty seconds duration. Each bin holds 20 ms. of spike data activity. Selection of the modes is automatically controlled by MINC. In addition, we built a stand-alone spike counter which displays the spontaneous rate of spikes per second.

Software: Software coordinates all external and MINC activities. Some activities occur simultaneously - most importantly data collection occurs while MINC controls the stimulus movement. There are three different types of program, all oriented to "user friendliness". The surveillance program collects data while the operator controls the stimulus; the program continuously calculates the spontaneous spike rate and the peak spike rate for collected data. The stimulus programs collect data and control the stimulus movement. There are five different packaged programs to choose from, providing a variety of tests for the nerve cells. The retrieval programs re histogram stored data on the screen and/or print out hard copy.

MINC allows precision in data collection stimulus control, a precision that was not possible with the traditional human subjective judgment methods.

I. HARDWARE

The external hardware, necessary to buffer spikes while stimulation programs are executed, consists of a memory chip and address counter PLUS the connections to MINC modules (a local bus). Figure A shows a block diagram outline of the various features of the hardware. Note that there is an independent "spontaneous rate" circuit shown in the lower right hand corner. Figure B shows more detail. The memory chip is Mostek's 4118 1k x 8 static RAM. AMD 25LS2569's are used for counters; they have tristate outputs and asynchronous CLEAR'S.

The input to the system is from a window discriminator which has separate upper and lower threshold levels. Figure C shows an example of a raw-data analog spike fitting between upper and lower windows. At the star a plus is produced, to be transmitted as the input to the hardware discussed here.

The specifications for the buffer circuit include two data collection modes. In Mode I, the 1024 word memory is filled in one second; i.e., each address represents one msec of data collection time. This would be used primarily to analyze very short, time-sensitive probes of the stimulus, for example ON-OFF responses. Mode II sorts the data into 1024 twenty msec memory addresses, giving a maximum sweep duration of twenty seconds. Accordingly, for any sweep of calculated duration greater than one second, the circuit automatically is shifted into Mode II.

Aside from the different maxium sweep durations, the two modes have the same features, including a MINC-controlled Read/write line and an, address reset line. The circuit was designed to send clock address information on four data lines, as well as display the current spontaneous spike rate per second. The spontaneous rate feature was implemented using hardware which requires no interaction from MINC.

For simplicity, the external memory buffer circuit may be divided into five sections: the dividing sequence, spike collection, the address counters, the memory chip, and spontaneous rate. Each is described below.

(i) Dividing sequence (See Figure D)

A 74LS124 oscillator chip, combined with a quartz crystal, was chosen to assure accuracy of circuit timing. The crystal determines the frequency of the oscillator output, exactly 1.024 MHz.

The 1.024 MHz. signal was sent through a series of dividers to achieve the required 50 Hz. and 1000 Hz. square waves for Modes I and II.

With this goal in mind, the CMOS4020, a 14 stage flip flop chain, was selected to be the divider. Its outputs are available at different frequencies, each successively divided by two. A 2kHz. signal was taken directly from this chip and sent to a multiplexer.

The multiplexer chosen was the 74LS153. Although it appears that a simple 2 to 1 MUX would be suitable for this situation, the 4 to 1 MUX was chosen to aid debugging. The four signals thus available to the user were 100Hz., 2kHz., 1kHz., and a signal from a hand-held pulse generator. The pulse generator signal was found to be particularly useful for debugging.

The multiplexer is controlled by two "select" lines which come directly from MINC (I/O #11, I/O #12). In the interest of "user friendliness", the mode selection is automatically made in the stimulus programs, based on sweep duration calculations.

For example, a sweep of duration less than one second will be in Mode I (1 ms. mode) and the 2kHz. signal, corresponding to a 1/2 ms period, will be selected. This is not the 1 ms. period signal needed

to increment the address counters; this 1/2 ms. period signal is used to trigger devices requiring rising or falling edges, as will be explained in more detail below.

To achieve the 1 ms./20 ms. period signals, the square wave was sent into the clock pin of a 74LS112, with the J and K pins of the flip flop tied high. Consequently, the output $\overline{Q}$ was halved, resulting in a kHz. or 50 Hz. signal, depending on the mode selected.

(ii) Spike Collection

Pulses are sent into the "clock" pin of an 25LS2569 counter. See Figure B again. In this manner, the counter can be incremented each time a spike is generated during a time bin. The counted data are sent to the memory chip (MK4118), to MINC (I/O 37, #7, #8, #9, #10), and to a bus data display (TIL311).

When the specified mode time (1 ms. or 20 ms.) has passed, the counter and the display must be cleared, and the data collection process must begin immediately again. The counter is cleared by a brief (140 ns = time low) one-shot (74121) pulse sent into the asynchronous clear of the counter. Data is sent off every 1 ms. or 20 ms., regardless of how many spikes occur in that amount of time. The display (TIL311) is latched by the inverted output of the multiplexer from the dividing sequence. A full clock pulse is required for the display to latch. Consequently, the period of the latching signal must be 12 ms. or 10 ms., depending on the operation mode.

One final issue to consider is the timing of the "output-enable" of the counter (2569). Certainly, one wants the counter to send data to the memor, chip only when the circuit is in the "write into memory" mode. Bus c ntention would occur if the output of the spike counter were not inhibited during the "read" mode. The memory chip would be

trying to send out the data in the current address of memory, while the counter would be trying to send data on the same bus. A signal from MINC (I/O #2 R/$\overline{W}$) is sent <u>directly</u> into the output enable ($\overline{OE}$) to prevent this from happening. This same signal is inverted and sent to the output enable of the memory chip. Hence, when one counter's output is operational, the other chip's output is inhibited. No bus contention occurs.

(iii) <u>Address Counters</u>

A group of three AM25LS2569 counters is cascaded together to increment the memory address. The clock pulses are received from the "Q" output of the 74121 in the spike collection segment of the circuit. These pulses are received every 1 ms. or 20 ms., depending on the mode. The ten least significiant digits are sent to the address lines of the memory chip. The output of the address counters is <u>always</u> enabled; MINC may want to access a memory address whether the buffer is in the read or write mode. Accordingly, the display that shows the eight least significant digits of the memory address must be interpreted as either the address being written into the memory or the address being read from the memory, depending on the mode. This address display is latched by the inverted output of the multiplexer in the dividing sequence, as used in the TIL311 display in the spike collection segment.

The memory address is cleared by loading zero's into each of the three counters. The loading inputs of the counters are all grounded. A load ($\overline{LOAD}$) signal comes from MINC (I/O #14). Note that the signal from MINC is sent through an inverter to assure the proper voltage (0 volts).

(iv) Memory Chip

The memory chip is the central part of the circuit. Everything is timed so the data will arrive properly at the memory chip. No data can be lost. No extra data can be read.

A timing diagram (see Figure E) shows how we guarantee that the circuit can read memory, clear memory, reset the address counters, and write into memory rapidly, sequentially and currently All these events occur in a time negligible compared to the total data collection period. A one-shot (74121, #2) was inserted to decrease the delay of the spike counter reset so the other events have time to occur.

As explained in the spike collection section, the output enable ($\overline{\text{OE}}$) of the memory chip is controlled by the inverted I/O#2 (R/$\overline{\text{W}}$) line from MINC.

The write enable ($\overline{\text{WE}}$) of the memory chip is controlled by the NAND of the $\overline{\text{OE}}$ signal and the output of the 74121#2. The resultant signal has a low time of 300 ns. per period.

As an example of the system's timing, imagine that you are testing a sweep of a five second duration. After operator entry of sweep length and speed, the circuit would automatically be put into the 20 ms. mode (Mode II). The dividing sequence would send 10 ms. and 20 ms. period signals to be used by the dislay latches and counting sequences, respectively. If the circuit were in the "write" mode, I/O#2 (R/$\overline{\text{W}}$) would be low, resulting in the spike counter (2569) being enabled, and the output of the memory chip being disabed. During the first 20msec., the spike counter would increment with each spike generated frfom the stimulation of the experimental animal. Immediately before the end of the 20 msec., the "write enable" of the

memory chip would be activated, and the data would be latched into memory at the current address. A few nanoseconds later, the spike counter would clear and the memory address counter would be incremented. This cycle would be repeated 250 times (5 sec. sweep/20 ms. per cycle = 250 cycles).

(v) Spontaneous Rate (See Figure F)

Each time a spike is generated by the experimental animal, it is sent into a pair of rippled decade counters and accumulated. Once a second, these 8-bit spontaneous rate data are latched, using two 74LS174 chips. The two four-bit words are fed into a 2-to-1 multiplexer. These four lines of multiplexed data are sent to a display driver (8856) and to a two digit LED display which displays the two least significant digits of spontaneous activity on a per second basis.

A 555 timer (set up in an astable multivibrator configuration with a period of one second) clocks the two latches (F4LS174) which hold the 8-bit wide spontaneous rate data received from the two decade counters (F4LS90). The same signal is sent through two inverters before it clears the counters. This guarantees proper timing of the circuit. Accordingly, data from the animal is collected by the counters latched and sent to the display. The counters are cleared each second.

The spontaneous rate segment of the circuit was designed to be a stand-alone feature. It does not need any signals from MINC to perform its function.

(vi) Microswitch on the Rotation Turntable

To minimize user-participation in tasks that the computer could easily handle, a microswitch was installed to detect a reference point for the rotation feature of the stimulus control (see Figure G). Exact rotation to a vertical orientation is necessary because the stimulus orientation needs a datum level from which to change angles. It is critical that the stimulus be positioned normal to the direction of sweep.

When tripped, the microswitch sends a high signal through an inverter to I/0#16 of MINC, on the Digital-In module.

II. SOFTWARE

The software coordinates all external buffer and MINC activities. Such acitities include (1) external collection and retrieval of spike date, (2) MINC control of the bar stimulus orientation, speed and sweep length, (3) MINC data analysis, including generation of histograms and (4) storage and display of results. Proper control necessitates that many of these activities occur simultaneously. The programs coordinate these various tasks while maximizing "user friendliness" by an interactive approach.

There are three types of programs in the software package:

(1) The surveillance program.

(2) The stimulus programs.

(3) The recall and printing programs.

Each type provides a different service to the automation process.

The surveillance mode represents the most basic aspects of the computerization process. In this mode, the operator physically controls stimulation while the external circuit collects data. MINC interleaves the external data collection with the internal data analysis. The computer continuously calculates the average spontaneous spike data rate and the

peak spike rate for data collected over a user specified 1 to 4 seconds.

The Stimulus programs are a series of related package programs which access a common core of routines. There are five stimulus programs. Each collects, histograms, and stores data, but the sweep pattern varies by program. some programs are rigidly set and involve little user input; others are more flexible and require operator decisions. The remainder of the SOFTWARE SECTION details these porgrams.

Finally, the printing programs rehistogram and print out data stored after running any of the five stimulus programs. These printing programs retrieve and display pertinent data not obvious to the user.

(i) The Surveillance Mode

As pointed out in the software overview, this mode interleaves the collection of new data with an immediate report of the last period's data. "Surveillance" reports the average and peak spike rates over the data collection period. MINC takes a longer time to analyze data than the external circuit takes to collect data, so the cycle time of the two interleaved functions is determined by the longer MINC internal period of data analysis.

The user inputs a desired data collection time period: 1, 2, 3, or 4 seconds. MINC sets the external buffer to the "write" (or data collection) mode and collects spikes in 20 msec bins over the desired collection period as described earlier in the hardware overview. MINC beeps to notify the operator that data collection has begun. When MINC finishes analyzing last time period's data, it begins a new analysis on the newly collected data. MINC reads each 20 ms. bin of data into its own array in the workspace (the place where the computer lists and executes the programs). It then calculates the spontaneous

and peak spike rates per second and prints the rates on the screen. If the operator wishes to reset the data collection time interval or exit the otherwise endlessly looping program, she simply types "R" for reset on the terminal keyboard and is prompted accordingly.

The spontaneous rate is calculated by summing all the 20 ms. bins of spike data for the collection time period and dividing by the collection time. The peak rate is determined by a search algorithm. MINC steps through the data array summing every cluster of five successive 20 ms. array elements. The cluster with the highest total represents the 100 ms. period (20 ms. X 5 clusters) with the highest activity. This cluster total is multiplied by ten to reflect a peak rate on a "per second" basis.

(ii) The Stimulus Mode

This mode controls the movement of the light bar stimulus and correlates the stimulus with the spikes collected in the buffer. When we analyze data in this mode we calculate the total spikes per stimulus sweep, and histogram the data. An option stores raw sweep data and labels information on disk for later retrieval and analysis. The five programs in this mode vary only in their length of data collection and the style, length, and speed of light stimulus sweep; each of the five perform similiar data collection, processing, histogramming and storing functions. Stimulus program flow of program control is as follows:

(1) Initialize.

(2) User specifications inputted.

(3) Sweep and collect data simultaneously.

(4) Histogram data.

(5) Store data.

(6) Exit the program.

In the subsequent sections, we will outline the common core of routines. See Figure H Stimulus Program Flow for detail. These are data collection, data processing, histogramming, and data storing. Next we will discuss the differences between the five programs. Finally, certain algorithms of interest from the stimulus programs will be described.

(iii) Data Collection

Each of the five stimulus programs directs nerve cell response data to the external circuit while MINC modules control the sweeping of the light stimulus. Up to twenty seconds of data may be collected in the 1K external memory buffer (per stimulus sweep when the 20 ms. mode is in operation). If the time of a light stimulus sweep is less than one second, the stimulus program automatically increases the address stepping rate through memory to 1 KHz, so a finer data time-stamping scale may be achieved without the operator specifically requesting it. See Figure "I", Date Collection, for program flow chart.

(iv) Data Processing

During the run of a stimulus program, several different sweep patterns may be used. In the "speeds" program, for example, there are sweeps at 2, 10, and 30 degrees per second. Each sweep of collected data must be stored in its appropriate storage area. Any sweep may have up to 1000 data points in the external memory buffer. The data is read up to MINCinto a 1000 x 1 array (internally called the "E"

array) immediately after the sweep is completed. The data are then moved into the appropriate columns of a virtual array file in a 100 x n array, where n is the number of categories of sweeps present in the particular stimulus program (for "Speeds", n=3).

Note that the intermediate "E" array is used as a transfer channel from the external memory buffer to the second disk's array storage. Direct transfer is not possible with MINC.

There is a user-specified averaging option, in which several sweep cycles in any stimulus program are combined. If the operator requests 4 cycles of sweeps in the "speeds" program, MINC would perform four sweeps at each of the three speeds; the latest collected data would be added to the previous cycle's data in the proper category. When all the sweeps had been executed, MINC would divide the current summed spike data element by the number of sweep cycles to achieve an average over that number of cycles in that array element of that category, for each array element.

(v) Histogramming

A histogram is a time line bargraph summary of spike acivity from the data collected during a stimulus sweep. After a stimulus program is completed, the operator may view selected histograms from the set of all categories in that stimulus program. In "Speeds", 2, 10, or 30 degree/sec. data in histogram form may be viewed.

In certain stimulus programs, the user may view up to twelve histograms. This viewing can waste time if the information is uninteresting or inconclusive. To prevent this, we developed a selection algorithm with which the user may choose exactly which histograms she would like to view. Her choice is based on a summary

listing on the terminal screen of the total spikes recorded per sweep category. The user may then view all, selected, or no histograms. Figure J shows how this process occurs. If the user decides to view only selected histograms, she is asked to inut how many histograms she would like to se, and then prompted to enter the chosen categories' selection numbers. The program loads these into an array, then finds and histograms the appropriate categories. The user may view a histogram for as long as she wishes; she simply presses the return on the keyboard to view the next histogram.

(vi) Data Storing

As mentioned earlier, spike data is stored in virtual array form on the secondary (SY1:) disk. After histogramming data, the user must decide whether to (1) delete the data from the disk, or (2) store the data for later retrieval, histogramming, and/or printing.

If the user opts to delete the data, she is specifically directed how to do so. Unfortunately, MINC's operations system requires deletion of files on the second disk to be done by the execution of a program. In a certain sense, then the user is responsible for her own disk maintenance.

The storing option is more easily implemented. If the user chooses to store the date, she is prompted to record label information in the computer's memory for later access. The program automatically opens this text file and stores the user's prompted responses. Label information stored includes cat number, sweep number, stimulus size, contrast, electrode depth, eye tested, and a comment. This data, along with information pertinent to execution of the recall programs, is stored in a text file on the secondary disk. Upon program exit,

the user is notified of the text and data file names and how to access them.

There are two files created when one stores a program; the data file and the pertinent cat information file. The two files are stored with the following naming convention:

> The user specified cat number and sweep number are concatenated to make the file name. The file type of the data file is DAT. The file type of the information file is TXT. The form of the file is SYI: filename, filetype.

We suggest in our user's guide that the operator prefix the cat number with the first name of the stimulus program. This serves as a reminder when running the recall and printing programs later.

(vii) Description of the Five Stimulus Programs

In the laboratory set up, analog signals from MINC, the laboratory joystick, and the circuit offset, knobs are amplified to control mirror movement. The reflection from the mirrors causes light stimulus movement on a screen facing the laboratory animal. Sweeping is achieved through proper control of the D-to-A DA signals. The screen is placed at a specific distance from the animal such that a sweep of two centimeters on the screen subtends a one degree arc in the cat's visual range. The stimulus programs vary only in sweeping patterns. The five different programs are outlined as follows:

a. Clock

The clock program performs two cycles of twelve sweeps "around the clock" on the light screen. These twelve sweeps are equi-oriented at 30 degree intevals (see Figure K, clock's 12 orientations) sweeping at 4 deg/sec. in a sweep of diameter 24 cm

(12 degrees). Each sweep duration is, therefore, three seconds long. The twelve sweeps center around a user-specified origin. The rectangular light stimulus is automatically oriented normal to the direction of the sweep by the program (see Figure L, sweep at 60 degrees). The light stimulus is visible only during sweeping times, the shutter is closed when data is not being collected.

b. Speeds

The speeds program sweeps at 2, 10 and 30 degrees per second (4.20, 60 cm/sec). The experiment user chooses a sweep center, as in the "clock" program, and also specifies a sweep orientation, from 0 to 359 degrees. The user specifies over how many cycles of the three speeds data will be averaged.

c. Manual

The manual program is the most flexible of the stimulus programs. the user must input up to six different orientations and chooses a sweep length diameter and speed. The program will average over any number of cycles, but must be told what that number is. To start, the operator simply places the stimulus at the sweep's center; the program automatically rotates to the appropriate orientations and sweeps and collects data accordingly. "Manual" is not suggested for ordinary use because data from one presentation is usually not compatible with data from another.

d. Double

Another test commonly performed on the laboratory cats involves sweeping around two different user-specified centers, one for each eye being tested. The Double program implements this specification. The user inputs sweep speed and orientation and

when prompted, used the joystick to move the stimulus to each of the two sweep centers and hits the keyboard return. The Double program then sweeps four times for the first eye's center, then four times for the second eye's center, and then repeats this cycle once. Each histogram viewed is, therefore, averaged over eight sweeps.

e. On-off

In the On-off program, the user specifies a time fór the light to be flashed on (without movement) and time for the light to be shuttered. Data is collected for a total time period of (off time) + (on time) + (off time) and captures the nerve cell's response to dark-to-light-to-dark transitions. The user picks an origin and MINC creates a three-by-three grid around that cener. The memory buffer collects data for all nine positions in the three by three grid, flashing off-on-off at each (see Fig. N). Each data collection point in the grid is separated 4 cm (2 deg.) from its neighbors.

If the user specifies the averaging option then the cycle of nine is repeated. The cycle is implemented in a pseudo-random order; See Fig. M for the sequence.

(viii) Two Algorithms used in the sweep generation

a. X and Y AxisG ain Differences

The op amp-servo motor systems which move mirrors for x and y deflection of the pattern on the screen have different overall gain factors. As a result an "analog out" step in the x direction is not equal to the same analog out signal in the y

direction. Different adjustment factors for length <u>and</u> <u>speed</u> had to be used in the x and y directions. A sweep at an orientation other than purely horizontal or purely vertical motion had a weighted average of the x and y factors in the sweeping algorithm. In the software mode, these adjustment factors are called F1 and F2 for the length of sweep, and S2 and S3 for the speed x and y adjustment factors, respectively. For example, for a 30 degree sweep, the number of values to send out by D/A conversion would be:

$$N1 = \frac{D \times (F1 \times \cos 30 + F2 \times \sin 30)}{s2 \times \cos 30 + s3 \times \sin 30}$$

b. <u>Sweeping Around Two Different Sweep Centers</u>

In the "Double" program, it is necessary to sweep about two centers. To be sure that noise and external influence such as joystick position would not cause MINC to miss the center locations, we sent signals from the scanning motor op amps back to analog-to-digital (A D) module of MINC. The Double program reads these A-D values as the positions of the two receptive field centers. Thus <u>feedback</u> is used to locate the centers.

A <u>search</u> algorithm was developed and implemented to re-find each inputted center. This algorithm is one of successive approximation, summarized by flow chart in Figure 0, "Horizontal Analog Search". The algorithms last guess jump is the final analog-out signal corresponding to the position that MINC originally read in and wanted to return to. This analog factor may then be correctly added to each element of the sweep stream to implement proper sweep length and speed.

(ix) User Notes for the Stimulus Programs

a. "Workspace" is the memory MINC reserves to hold and run a program. Due to the large size of the stimulus programs, EXTRA workspace must be obtained before any stimulus programs may be run. This must be done in the immediate mode of MINC. At the beginning of use, after a "Ready" prompter on the screen, the user is in the immediate mode and simply types EXTRA-SPACE one time and answers Y when the computer asks if the user is ready to change the workspace.

b. Whenever an array is opened in the workspace, that array is automatically zeroed. When an array is opened on the secondary disk, however, it is not automatically zeroed. The stimulus programs do this. Only array elements needed for collecting each category's data are zeroed out. This process, however, uses up considerable MINC time and slows down the rate of data processing. When data files are erased from the secondary (SY1:) disk, a gap is left in its place. these gaps are occasionally too small to be useful. Many such gaps may accumulate on the disk, "filling up" a disk which still has a lot of space. Occasionally, the operator should type in the immediate (READY) mode, 'COLLECT SY1:". This packs the programs and data into one region of the disk, and leaves all unused space in one large area.

(x) The Recall and Printing Programs

In the stimulus programs, each program has a storage option in which the sweep data and text information can be put on disk for later retrieval. As noted before, this information is stored in virtual

array files. Retrieved in raw form, this information is a garbled mess! A series of recall "interpreptation" programs, therefore, were written. Originally it was intended to incorporate printing into the stimulus programs. This is impossible because of computer workspace limitations. We intended to write only one generic retreival program for all five stimulus programs. This was impossible because the stored information was too varied to be covered by one MINC BASIC program. Consequently, five retrieval programs were written, each streamlined to fit its counterpart stimulus program. Each program rehistograms and/or prints out the data. When text information is stored in a stimulus program, pertinent information for rehistogramming is also stored and passed on to the rehistogramming program.

Each of the programs is called XHISTO where the variable is the first letter from the stimulus programs's title:

CLOCK - - - - CHISTO

SPEEDS- - - - SHISTO

MANUAL- - - - MHISTO

DOUBLE- - - - DHISTO

ONOFF - - - - OHISTO

The user types "run XHISTO and is prompted to enter the cat number and sweep number. The computer automatically displays the comments, depth, total spikes, etc., that were set in the stimulus program. Much like the stimulus programs, the XHISTO programs offer the options of viewing all, selected, or no histograms. The user may specify a new bin width for histogram viewing.

After histogramming, the user chooses either to print out the data or to exit the program. If she opts to print, the lab information entered by

the operator in the stimulus program is put out on the EPSON 100, in table form. See Figure P for details of printing process.

There is a printing limitation, however; the data buffer that holds the information to be printed is of limited size (2K). Only about 70-80 lines of information may be printed before overflow. An algorithm was developed that groups data bins together so that the line limit is not surpassed. This limit is neither exceeded nor underestimated. Methods used to save printout space and maintain meaningful data resolution were (1) arranging the data in three columns across the page, maximizing page width instead of length, and (2) accumulating data according to the sweep duration and the actual number of array elements used. (3) The printer is imperfect in another way; the buffer always holds the last few lines of the print in the buffer without printing them. This problem is avoided by making sure that the last few lines of the material to be printed are blank lines.

When the user stores the cat number in the stimulus program, it is suggested in the user's guide that she store X166 (X an element of C,S, M,D,O) instead of the usual K166 to help him remember which stimulus program the data came from when running the XHISTO program.

REFERENCES

Advanced Micro Devices, Inc, Schottky and Low Power Schottky Data Book, Sunnyvale, CA, Advanced Micro Devices, Inc., 1977, p. 3-262.

Digital Equipment Corp. Minc User's Manual's, Vols 1-8, Atlanta, Digital Equip. Corp., 1978.

Mostek Corp., Memory Data Book and Designer's Guide, Texas, Mostek Corp., 1979, p. 155.

National Semiconductor, CMOS Data Book, Santa Clara, CA, National Semiconductor, Inc., 1977, p. 2-57.

National Semiconductor, Linear Data Book, Santa Clara, CA, National Semiconductor, Inc., 1978, p. 9-26.

Texas, Instruments, TTL Data Book, New York, Texas Instruments, 1979.

APPENDIX I

MINC CONNECTOR LINES

Digital In Connections

DIN #2, #3, #4, #5. Spike data from the external memory buffer. When this data is read into MINC from the buffer, it automatically receives proper binary wieghting. The data word is read into the workspace E array as outlined in the data collection section.

DIN #6. Clock address information. This line receives a square wave every time the external memory's address lines are updated. This line is not used presently in any program.

DIN #7. Microswitch line. This line goes low when the microswitch is tripped. This gives a reference point from where the stimulus rotator may base its angle measurements.

Digital Out Connections - These lines are inverted upon output.

DOUT #1, #2. Rotation lines controlling the stimulus orientation. Line #1 controls clockwise motion and line #2 controls counterclockwise rotation of the light stimulus. Each line is originally set low in the stimulus programs to avoid random noise fluctuations. Each line requires a square wave to drive a stepping motor in the proper direction.

DOUT #3. Light shutter. This line shutters and unshutters the light stimulus' image on the screen. The light is unshuttered during sweeping and when the monitor sets sweep center. Setting this line to 0 leaves the shutter open; a 1 on this line closes the shutter.

DOUT #5. Read/$\overline{\text{Write}}$. This line controls the memory mode. A 0 on this line puts the 4118 memory chip in the Read mode, and a 1 puts it into the Write mode.

DOUT #10. Load in zeroes. This line resets the memory address counters by loading zeroes into the counters outputs. A 1 on this line allows the counters to count normally; a 0 on this line activates the loading function.

DOUT #11, #9. Mux Selects A and B for the Ls153 Multiplexor. Line assignments are as follows:

(0,0) = 1kHz from MINC
(0,1) = Logic Pulse Generator
(1,0) = 1 ms. mode
(1,1) = 20 ms. mode

Setting these lines in one of these four manners controls the rate at which memory is incremented.

Analog In Lines

AIN #4. This line inputs the horizontal position of the light stimulus on the screen (x coordinate).

AIN #5. This line inputs the vertical position of the light stimulus on the screen (y coordinate).

Analog Out Lines

AOUT #0. This line controls the horizontal position of the light stimulus on the light screen.

AOUT #1. This line controls the vertical position of the light stimulus on the light screen.

APPENDIX II

EXTERNAL MEMORY BUFFER I/O LINES

Wire color on circuit	Wire color to MINC	# on circuit diagram	# on MINC	Line Name	Connections to buffer circuit
Red	White	1	--	+ 5 volts	+ 5 volts
White	Yellow	2	Dout#5	R/$\overline{W}$	spike 2569, pin 17 7404#1, pin 13
Pink	Pink	3	Din #6	Clock Address Information	74121#1, pin 3
Green	Thin White	6	window discrimin.	Spikes	2569(sp), pin 2 1s90#1, pin 14
Green	Green	7	Din #2	Data LSB	2569(sp), pin 16 4118, pin 9
Purple	Purple	8	Din #3	Data 2SB	2569(sp), pin 15 4118, pin 10
Blue	Blue	9	Din #4	Data 3SB	2569(sp), pin 14 4118, pin 11
Pink	Pink	10	Din #5	Data MSB	2569(sp), pin 13 4118, pin 13
Pink	Pink	11	Dout #11	MuxSel A	153, pin 14
Orange	Orange	12	Dout #9	MuxSel B	153, pin 2
Black	Black	13	--	Ground	Ground
Pink	Pink	14	Dout #10	Counter Clear	7404#2, pin 9
Yellow	White	15	Microswitch	Microswitch	7404#2, pin 1
Blue	Purple	16	Din #[illegible]	Inverted Microswitch	7404#2, pin 2

APPENDIX III

"CLOCK" Printout

THIS IS FROM THE CLOCK PROGRAM

CAT NUMBER: C

SWEEP NUMBER: C

CHANNEL: W

DEPTH: D

OPEN EYE: B

STIMULUS SIZE: T

CONTRAST: F

COMMENT: C

SWEEP DURATION: 3 SEC

RADIUS: 12 DEG

SPEED: 4 DEG/SEC

AVERAGED OVER 2 SWEEPS

	ORIENTATION											
MSEC	0	30	60	90	120	150	180	210	240	270	300	330
0	5.0	3.0	4.0	3.0	4.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
60	3.0	5.0	4.0	3.0	4.0	3.0	3.0	3.0	3.0	3.0	4.0	3.0
120	4.0	3.0	3.0	3.0	3.0	3.0	5.0	3.0	3.0	3.0	4.0	3.0
180	4.0	5.0	5.0	3.0	5.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
240	3.0	4.0	3.0	3.0	3.0	3.0	4.0	3.0	3.0	3.0	5.0	3.0
300	5.0	3.0	3.0	3.0	3.0	3.0	4.0	3.0	3.0	3.0	3.0	3.0
360	3.0	5.0	5.0	3.0	5.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
420	3.0	3.0	3.0	3.0	3.0	3.0	5.0	3.0	3.0	3.0	5.0	3.0
480	5.0	4.0	4.0	3.0	4.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
540	3.0	5.0	3.0	3.0	4.0	3.0	3.0	3.0	3.0	3.0	5.0	3.0
600	4.0	3.0	3.0	3.0	3.0	3.0	5.0	3.0	3.0	3.0	4.0	3.0
660	4.0	4.0	5.0	3.0	5.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
720	3.0	4.0	3.0	3.0	3.0	3.0	4.0	3.0	3.0	3.0	5.0	3.0
780	5.0	3.0	3.0	3.0	3.0	3.0	4.0	3.0	3.0	3.0	3.0	3.0
840	3.0	4.0	4.0	3.0	5.0	3.0	3.0	3.0	3.0	3.0	4.0	3.0
900	3.0	3.0	3.0	3.0	3.0	3.0	5.0	3.0	3.0	3.0	5.0	3.0
960	5.0	3.0	4.0	3.0	4.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
1020	3.0	5.0	4.0	3.0	4.0	3.0	3.0	3.0	3.0	3.0	4.0	3.0
1080	4.0	3.0	3.0	3.0	3.0	3.0	5.0	3.0	3.0	3.0	3.0	3.0

1140	4.0	5.0	5.0	3.0	5.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
1200	3.0	3.0	3.0	3.0	3.0	3.0	4.0	3.0	3.0	3.0	6.0	3.0
1260	5.0	3.0	4.0	3.0	3.0	3.0	4.0	3.0	3.0	3.0	3.0	3.0
1320	3.0	5.0	4.0	3.0	5.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
1380	3.0	3.0	3.0	3.0	3.0	3.0	5.0	3.0	3.0	3.0	5.0	3.0
1440	5.0	4.0	5.0	3.0	4.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
1500	3.0	4.0	3.0	3.0	4.0	3.0	3.0	3.0	3.0	3.0	5.0	3.0
1560	4.0	3.0	3.0	3.0	3.0	3.0	5.0	3.0	3.0	3.0	4.0	3.0
1620	4.0	5.0	5.0	3.0	5.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
1680	3.0	3.0	3.0	3.0	3.0	3.0	4.0	3.0	3.0	3.0	5.0	3.0
1740	5.0	3.0	4.0	3.0	3.0	3.0	4.0	3.0	3.0	3.0	3.0	3.0
1800	3.0	5.0	4.0	3.0	5.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
1860	3.0	3.0	3.0	3.0	3.0	3.0	5.0	3.0	3.0	3.0	4.0	3.0
1920	5.0	4.0	5.0	3.0	4.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
1980	3.0	4.0	3.0	3.0	4.0	3.0	3.0	3.0	3.0	3.0	4.0	3.0
2040	4.0	3.0	3.0	3.0	3.0	3.0	5.0	3.0	3.0	3.0	4.0	3.0
2100	4.0	5.0	5.0	3.0	5.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
2160	3.0	3.0	3.0	3.0	3.0	3.0	4.0	3.0	3.0	3.0	4.0	3.0
2220	5.0	3.0	4.0	3.0	3.0	3.0	4.0	3.0	3.0	3.0	3.0	3.0
2280	3.0	5.0	4.0	3.0	5.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
2340	3.0	3.0	3.0	3.0	3.0	3.0	5.0	3.0	3.0	3.0	5.0	3.0
2400	5.0	4.0	5.0	3.0	4.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
2460	3.0	4.0	3.0	3.0	4.0	3.0	3.0	3.0	3.0	3.0	4.0	3.0
2520	4.0	3.0	3.0	3.0	3.0	3.0	5.0	3.0	3.0	3.0	3.0	3.0
2580	4.0	5.0	5.0	3.0	5.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
2640	3.0	3.0	3.0	3.0	3.0	3.0	4.0	3.0	3.0	3.0	5.0	3.0
2700	5.0	3.0	4.0	3.0	3.0	3.0	4.0	3.0	3.0	3.0	3.0	3.0
2760	3.0	5.0	4.0	3.0	5.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
2820	3.0	3.0	3.0	3.0	3.0	3.0	5.0	3.0	3.0	3.0	5.0	3.0
2880	5.0	4.0	5.0	3.0	4.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
2940	3.0	4.0	3.0	3.0	4.0	3.0	3.0	3.0	3.0	3.0	4.0	3.0
TOTAL	188	189	186	150	188	150	186	150	150	150	188	150

APPENDIX IV

"SPEEDS" Printout

```
THIS IS FROM THE SPEEDS PROGRAM
CAT NUMBER:                     T
SWEEP NUMBER:                   L
CHANNEL:                        NORTH
DEPTH:                          SHORT
OPEN EYE:                       R
STIMULUS SIZE:                  LARGE
CONTRAST:                       AMAZING
ORIENTATION:                    60
SWEEP RADIUS:                   10
AVERAGED OVER 1 SWEEPS
COMMENT:   BRU IS SO FORMATTED.
SPEED:  2  DURATION: 5                TOTAL SPIKES: 250
SPEED: 10  DURATION: 1                TOTAL SPIKES: 63
SPEED: 30  DURATION: .33333           TOTAL SPIKES: 5
```

	SPEED				SPEED				SPEED		
MSEC	2	10	30	MSEC	2	10	30	MSEC	2	10	30
0	2.0	4.0	2.0	40	2.0	2.0	2.0	80	2.0	2.0	1.0
120	2.0	2.0	0.0	160	2.0	3.0	0.0	200	2.0	2.0	0.0
240	2.0	2.0	0.0	280	2.0	2.0	0.0	320	2.0	4.0	0.0
360	2.0	2.0	0.0	400	2.0	2.0	0.0	440	2.0	2.0	0.0
480	2.0	4.0	0.0	520	2.0	2.0	0.0	560	2.0	2.0	0.0
600	2.0	2.0	0.0	640	2.0	4.0	0.0	680	2.0	2.0	0.0
720	2.0	2.0	0.0	760	2.0	2.0	0.0	800	2.0	4.0	0.0
840	2.0	2.0	0.0	880	2.0	2.0	0.0	920	2.0	2.0	0.0
960	2.0	4.0	0.0	1000	2.0	0.0	0.0	1040	2.0	0.0	0.0
1080	2.0	0.0	0.0	1120	2.0	0.0	0.0	1160	2.0	0.0	0.0
1200	2.0	0.0	0.0	1240	2.0	0.0	0.0	1280	2.0	0.0	0.0
1320	2.0	0.0	0.0	1360	2.0	0.0	0.0	1400	2.0	0.0	0.0
1440	2.0	0.0	0.0	1480	2.0	0.0	0.0	1520	2.0	0.0	0.0

APPENDIX V

THIS IS FROM THE ON OFF PROGRAM
CAT NUMBER: X
SWEEP NUMBER: X OPEN EYE: R
CHANNEL: E STIMULUS SIZE: S
DEPTH: D CONTRAST: C
ON TIME: 2 OFF TIME: 1
COMMENT: TEST PROGRAM
AVERAGED OVER 1 SWEEPS

NUM	1	6	7	3	2	8	4	9	5
POSN	-2 2	2 0	-2 -2	2 2	0 2	0 -2	-2 0	2 -2	0 0

ORIENTATION NUMBER

	MSEC	1	6	7	3	2	8	4	9	5
OFF	0	4.00	5.00	4.00	5.00	5.00	5.00	6.00	6.00	4.00
OFF	80	6.00	5.00	4.00	4.00	5.00	4.00	4.00	4.00	6.00
OFF	160	4.00	4.00	6.00	6.00	4.00	6.00	6.00	6.00	4.00
OFF	240	4.00	6.00	4.00	4.00	6.00	4.00	4.00	4.00	5.00
OFF	320	6.00	4.00	6.00	5.00	4.00	5.00	4.00	4.00	5.00
OFF	400	4.00	5.00	4.00	5.00	5.00	5.00	6.00	6.00	4.00
OFF	480	5.00	5.00	4.00	4.00	5.00	4.00	4.00	4.00	6.00
OFF	560	4.00	4.00	6.00	6.00	4.00	6.00	6.00	6.00	4.00
OFF	640	4.00	6.00	4.00	4.00	6.00	4.00	4.00	4.00	5.00
OFF	720	6.00	4.00	6.00	5.00	4.00	5.00	4.00	4.00	5.00
OFF	800	4.00	5.00	4.00	5.00	5.00	5.00	6.00	6.00	4.00
OFF	880	6.00	5.00	4.00	4.00	5.00	4.00	4.00	4.00	6.00
OFF	960	4.00	4.00	6.00	6.00	4.00	6.00	6.00	6.00	4.00
ON	1040	4.00	6.00	4.00	4.00	6.00	4.00	4.00	4.00	5.00
ON	1120	6.00	4.00	6.00	5.00	4.00	5.00	4.00	4.00	5.00
ON	1200	4.00	5.00	4.00	5.00	5.00	5.00	6.00	6.00	4.00
ON	1280	6.00	5.00	6.00	4.00	5.00	4.00	4.00	4.00	6.00
ON	1360	4.00	4.00	4.00	6.00	4.00	6.00	6.00	6.00	4.00
ON	1440	4.00	6.00	4.00	4.00	6.00	4.00	4.00	4.00	5.00
ON	1520	5.00	4.00	6.00	5.00	4.00	5.00	4.00	4.00	7.00
ON	1600	4.00	5.00	4.00	5.00	5.00	5.00	6.00	6.00	4.00

APPENDIX VI

"DOUBLE" Printout

THIS IS FROM THE DOUBLE PROGRAM
CAT NUMBER: D
SWEEP NUMBER: D
CHANNEL: E
DEPTH: D
OPEN EYE: B
STIMULUS SIZE: S
CONTRAST: C
COMMENT: NOW BOTH EYES ARE RECEIVING DATA
SWEEP DURATION (SEC): 2
RADIUS (DEG): 10
SPEED (DEG/SEC): 5
AVERAGED OVER EIGHT SWEEPS
RIGHT EYE TOTAL SPIKES: 120.25
LEFT EYE TOTAL SPIKES: 120

MSEC	RIGHT	LEFT	MSEC	RIGHT	LEFT	MSEC	RIGHT	LEFT
20	1.25	1.00	40	1.25	1.25	60	1.00	1.75
80	1.00	1.75	100	1.25	1.25	120	1.25	1.00
140	1.25	1.00	160	1.25	1.00	180	1.25	1.00
200	1.25	1.00	220	1.25	1.00	240	1.25	1.25
260	1.00	1.75	280	1.00	1.75	300	1.25	1.25
320	1.25	1.00	340	1.25	1.00	360	1.25	1.00
380	1.25	1.00	400	1.25	1.00	420	1.25	1.00
440	1.25	1.25	460	1.00	1.75	480	1.00	1.75

APPENDIX VII

"MANUAL" Printout

THIS IS FROM THE MANUAL PROGRAM

CAT NUMBER:	M
SWEEP NUMBER:	M
CHANNEL:	E
DEPTH:	D
OPEN EYE:	E
STIMULUS SIZE:	S
CONTRAST:	C
COMMENT:	S
SWEEP DURATION:	1.5
RADIUS:	12
SPEED:	8 DEG/SEC

AVERAGED OVER 3 SWEEPS

	ORIENTATION					
MSEC	0	30	60	90	120	150
0	2.00	2.33	2.33	2.00	2.00	2.67
40	2.67	2.00	2.33	2.00	2.67	2.00
80	2.00	2.00	2.33	2.00	3.33	2.00
120	2.00	2.33	2.33	3.33	2.00	2.00
160	2.00	2.33	2.33	2.00	2.00	2.33
200	2.67	2.00	2.33	2.00	3.00	2.00
240	2.00	2.00	2.33	2.00	3.33	2.00
280	2.00	2.33	2.33	3.33	2.00	2.00
320	2.00	2.33	2.33	2.00	2.00	2.67
360	2.67	2.00	2.33	2.00	2.67	2.00
400	2.00	2.00	2.33	2.00	2.33	2.00

FIGURE A

CIRCUIT FLOW CHART

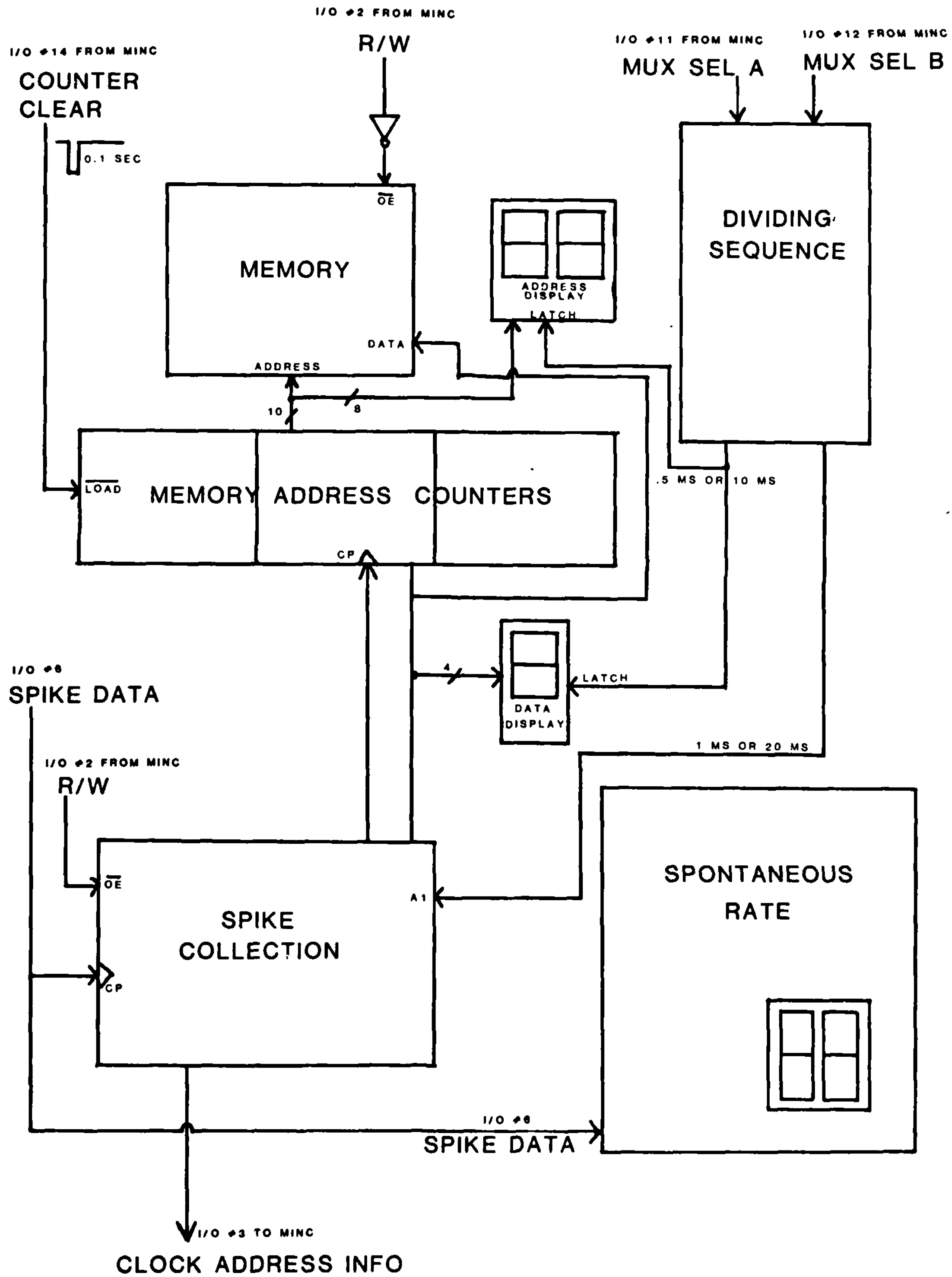
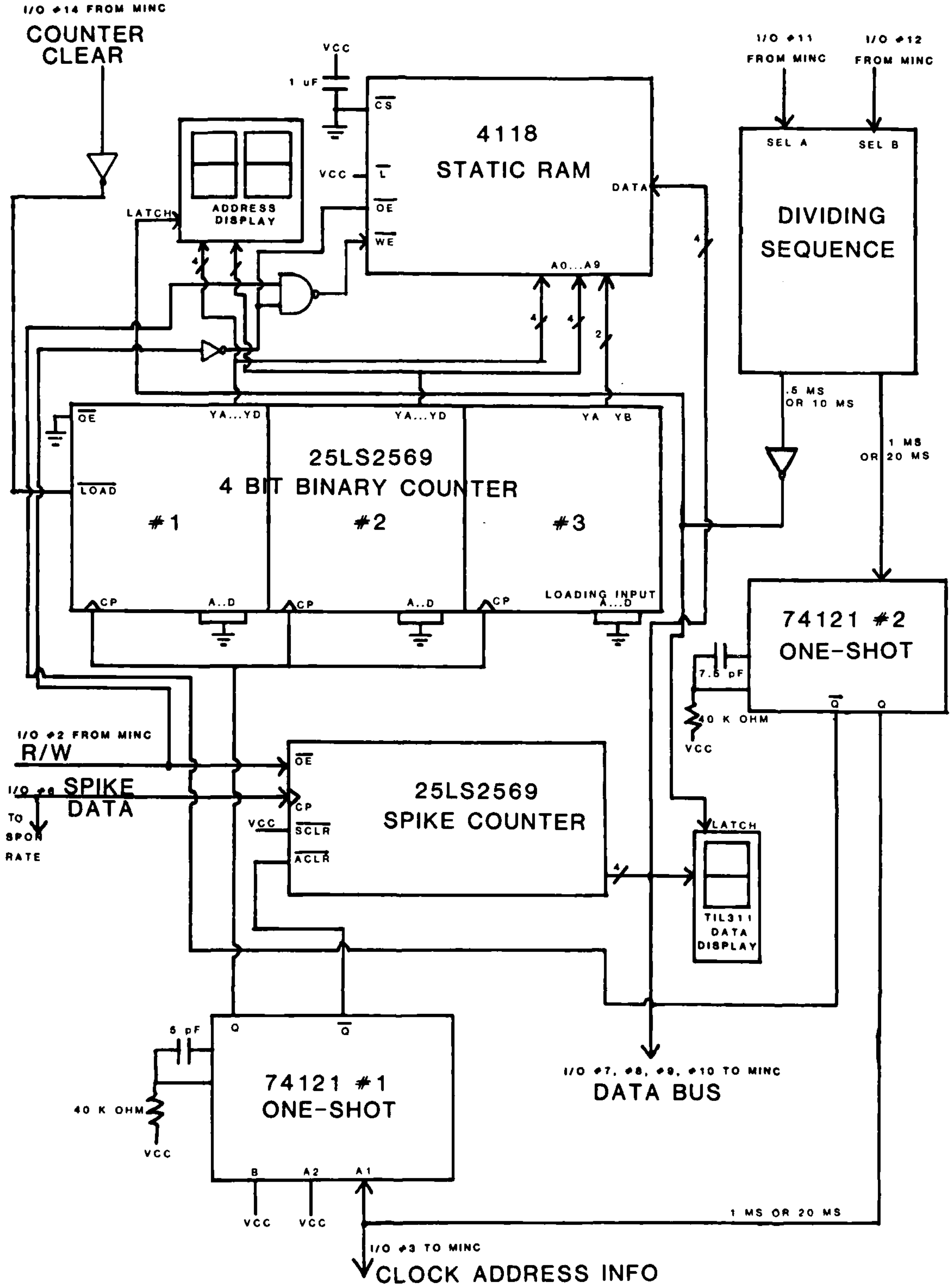


FIGURE B

MEMORY BUFFER CIRCUIT



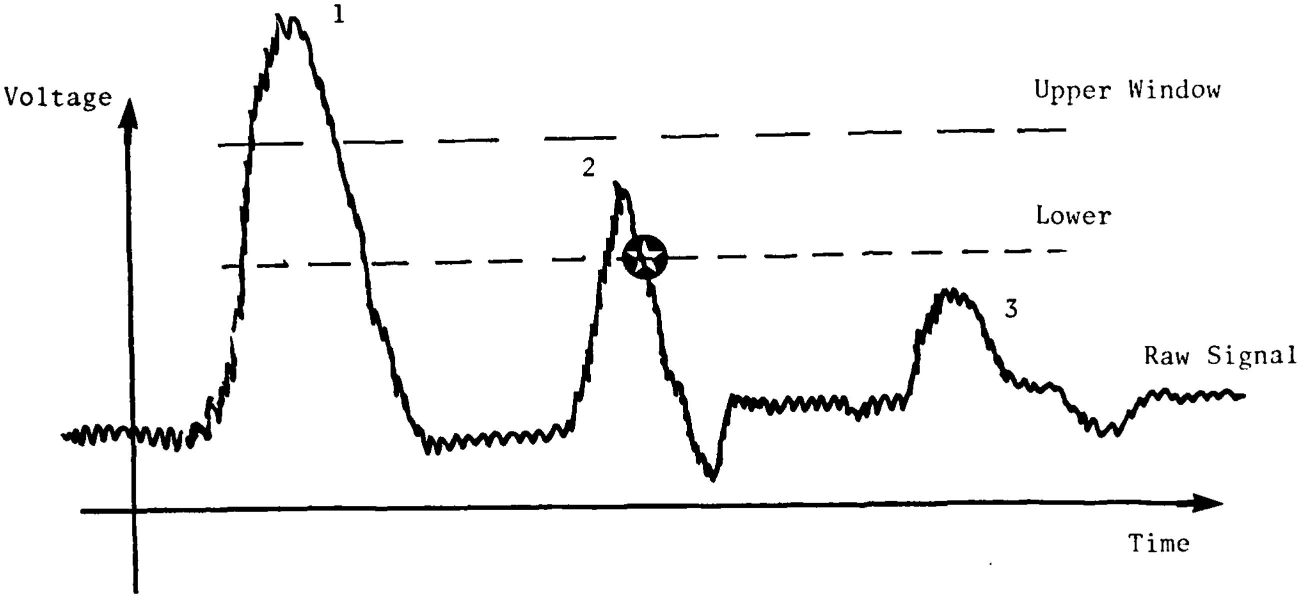


FIGURE C

Example of window discriminator detecting a spike. At ✪ the circuit produces a pulse. Waveform 1 is too large; waveform 3 is too small.

FIGURE D

DIVIDING SEQUENCE

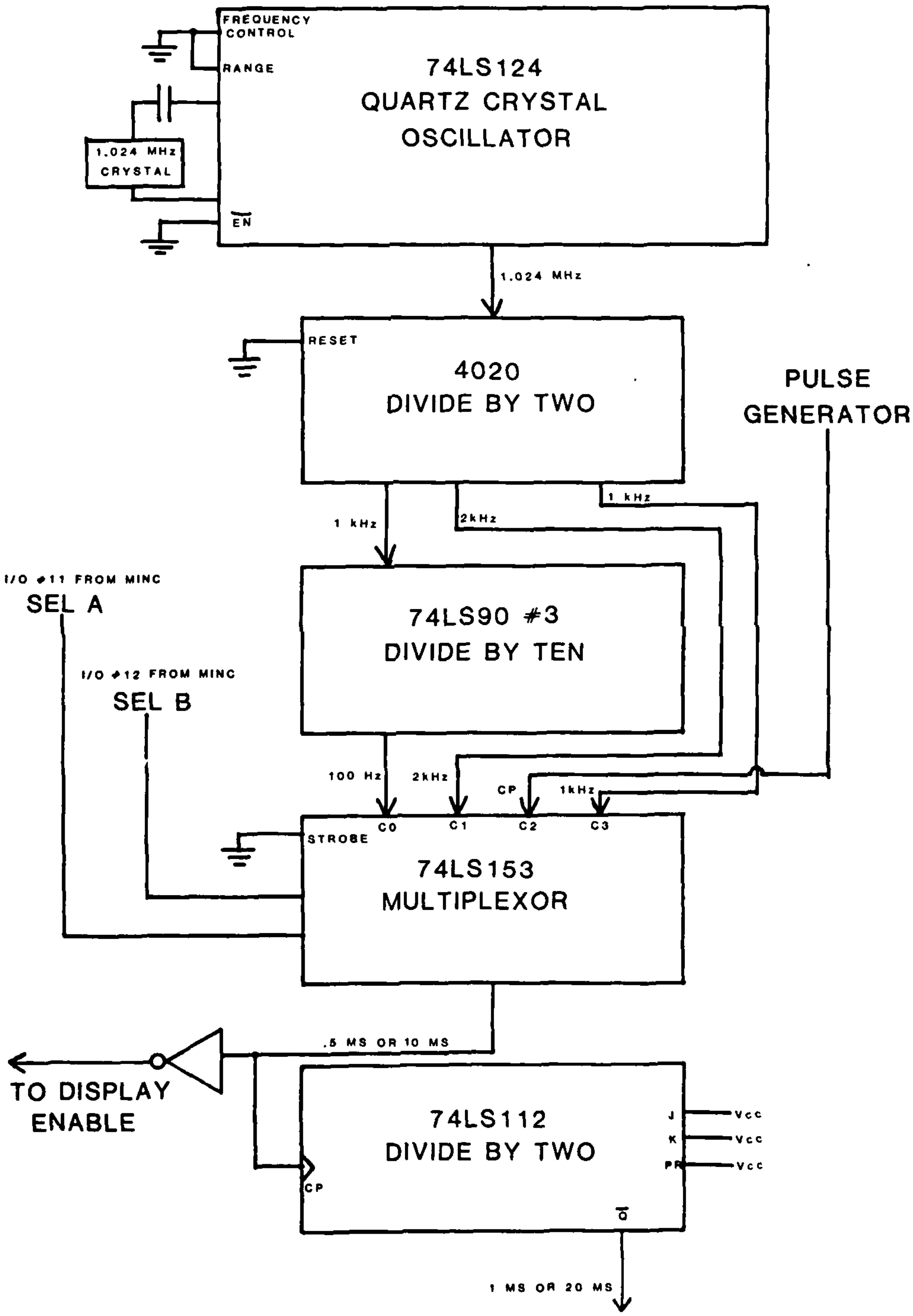
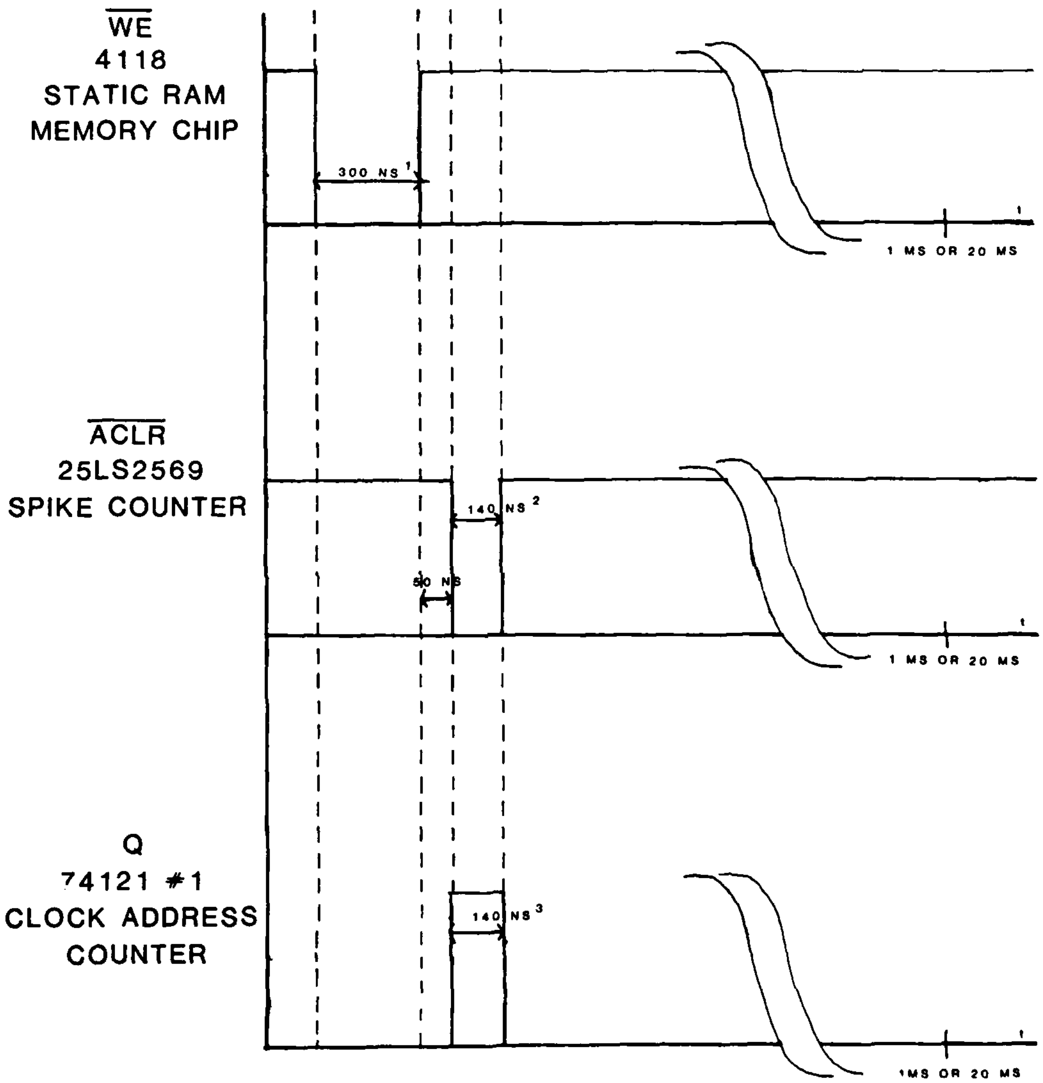


FIGURE E

TIMING DIAGRAM



SPECIFICATIONS FROM TIMING DATA SHEET

[1] T(low) ≥ 70NS

[2] T(low) ≥76 NS

[3] T(high) ≥76 NS

SPONTANEOUS RATE

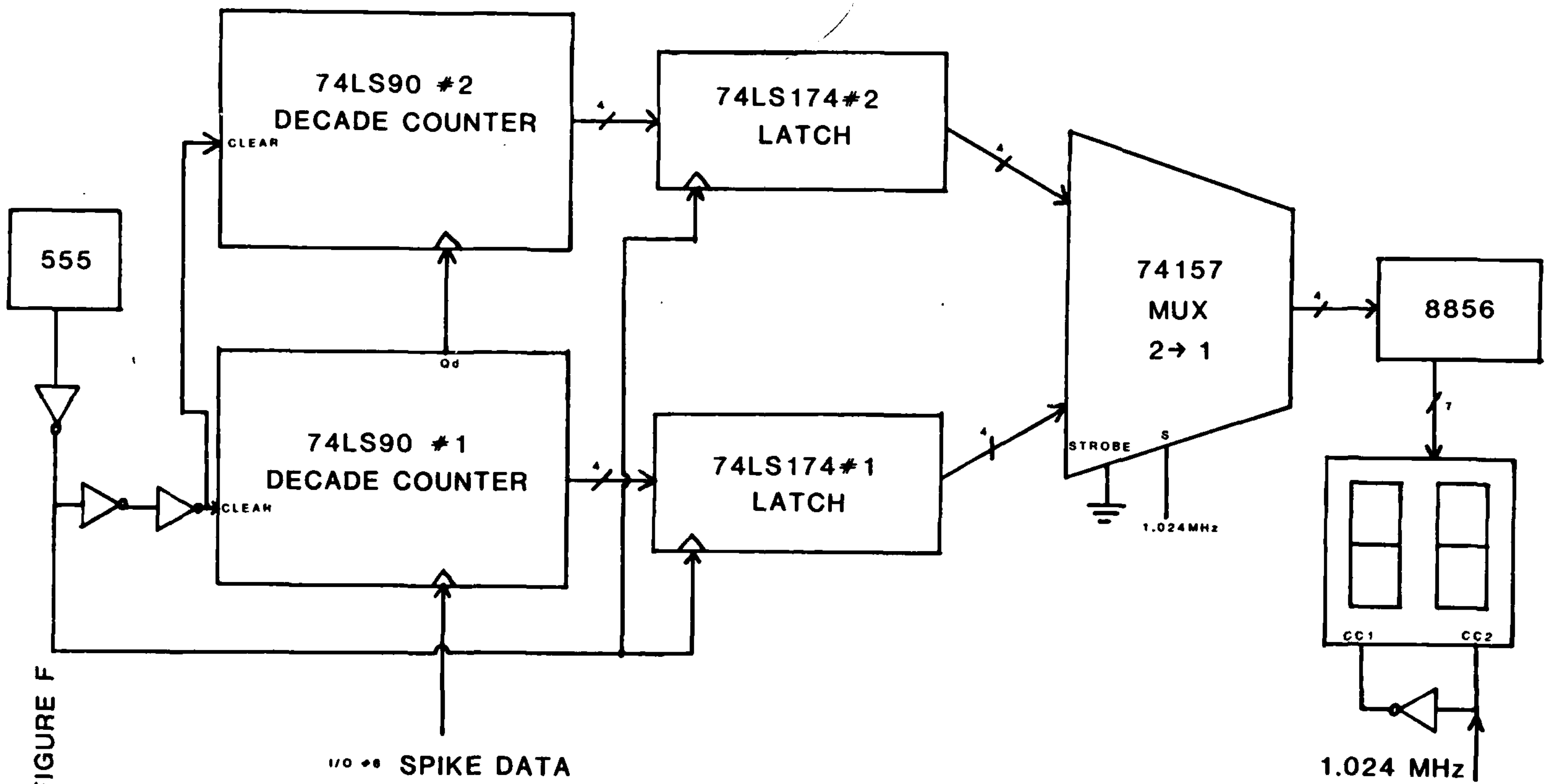


FIGURE F

MICROSWITCH

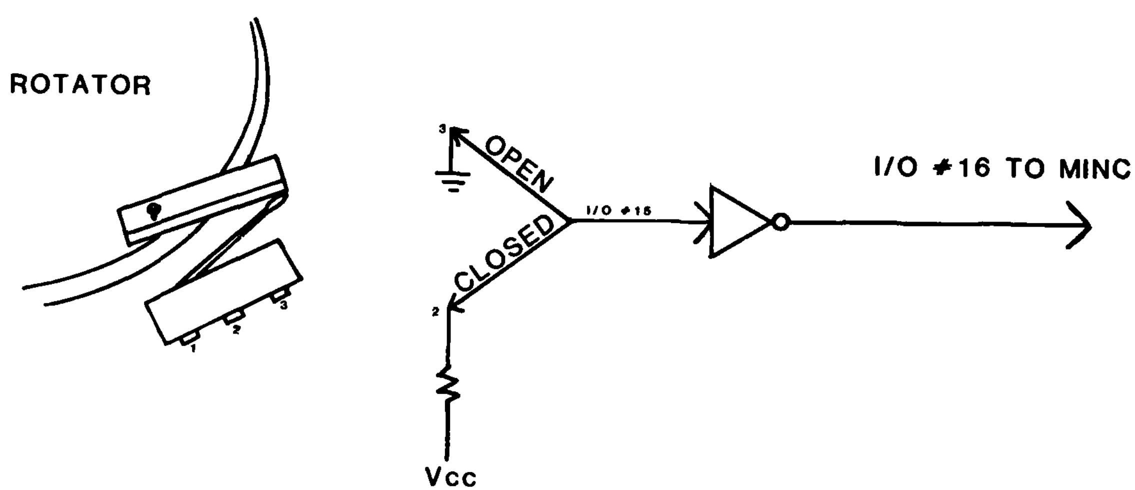


FIGURE G

FIGURE H.
STIMULUS PROGRAM FLOW

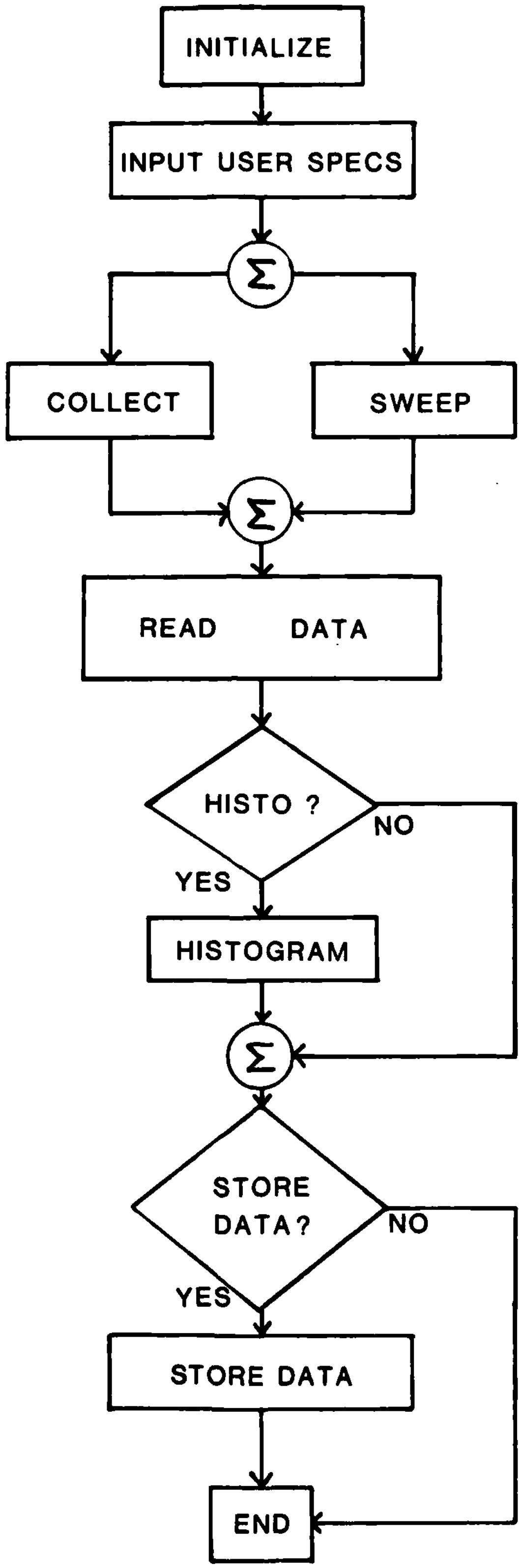


FIGURE I.

DATA COLLECTION

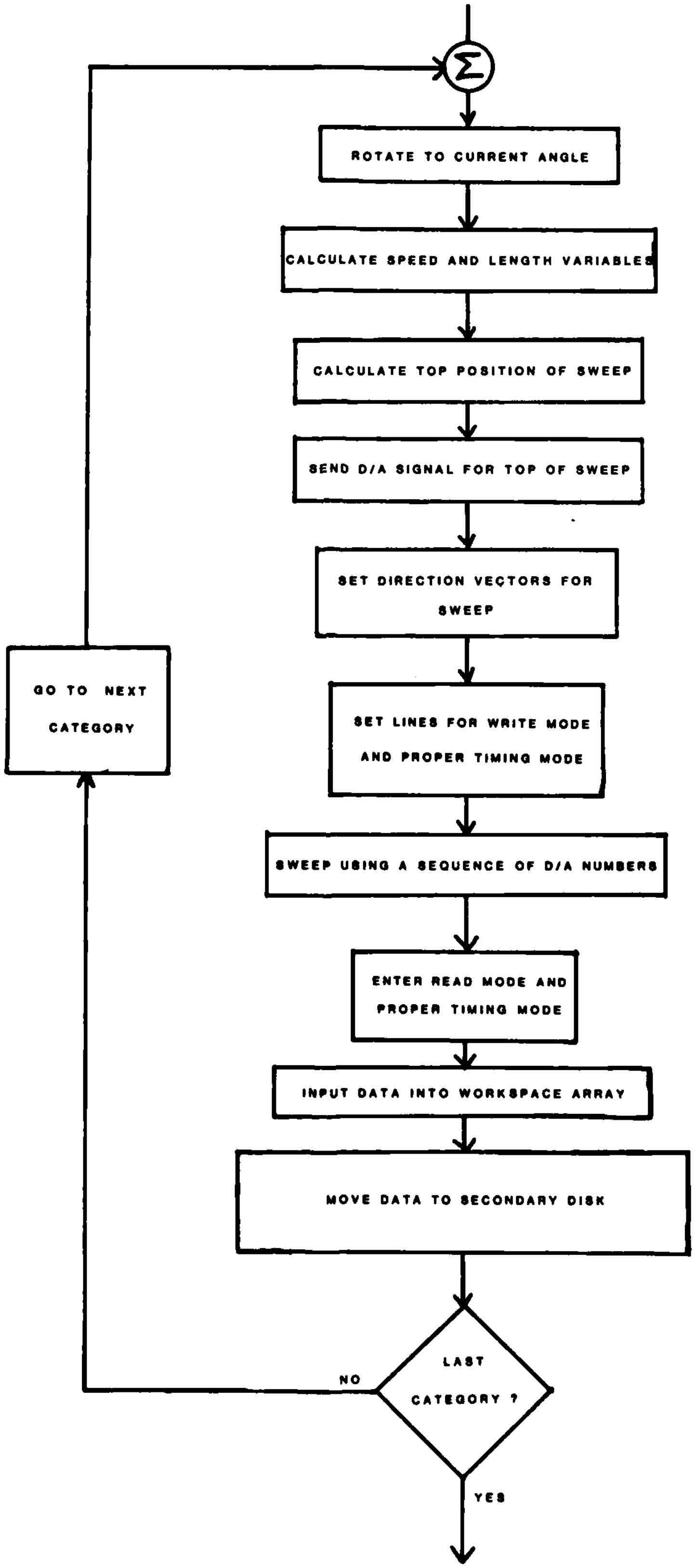


FIGURE J **HISTOGRAMMING**

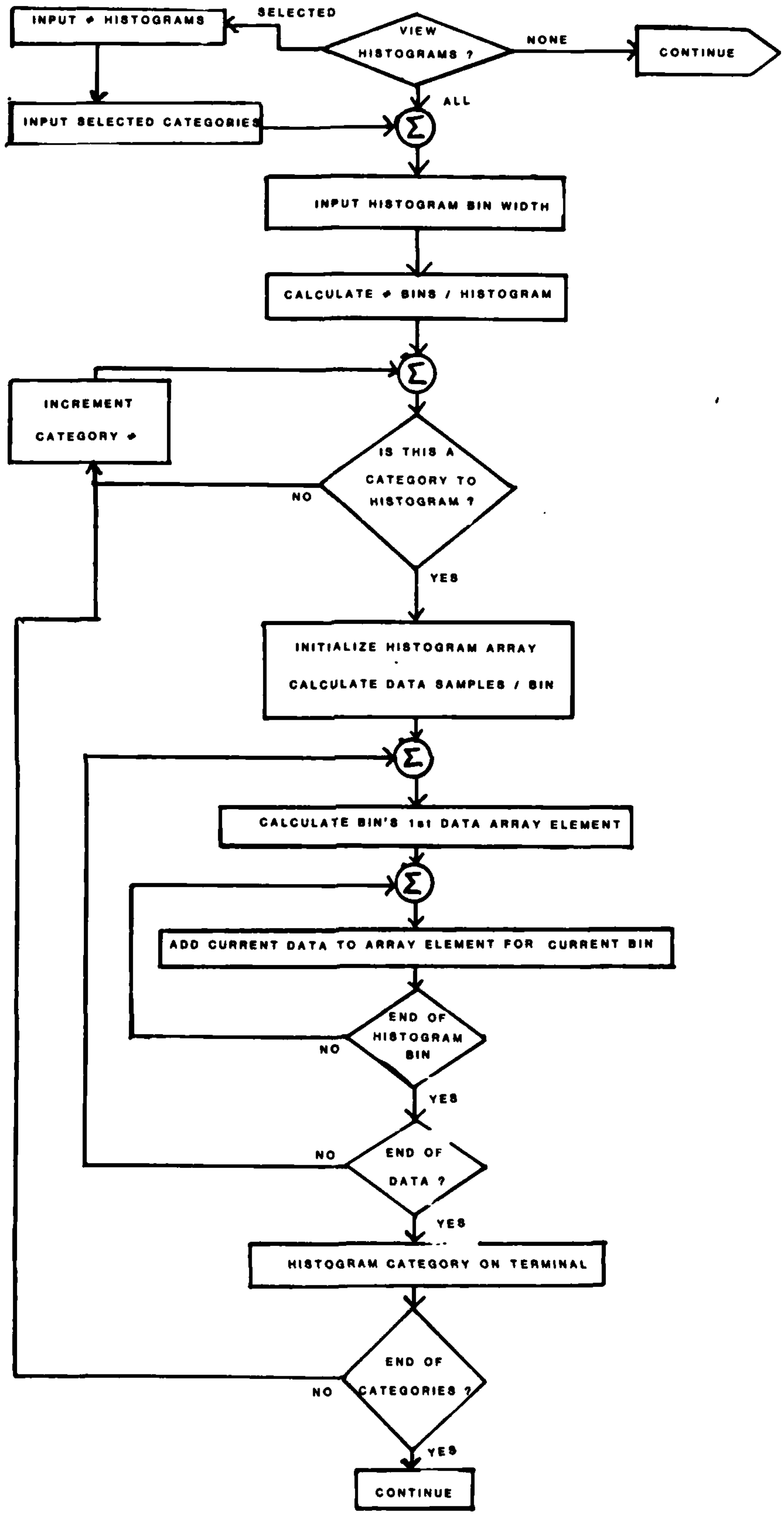


FIGURE K.. CLOCK'S 12 ORIENTATIONS

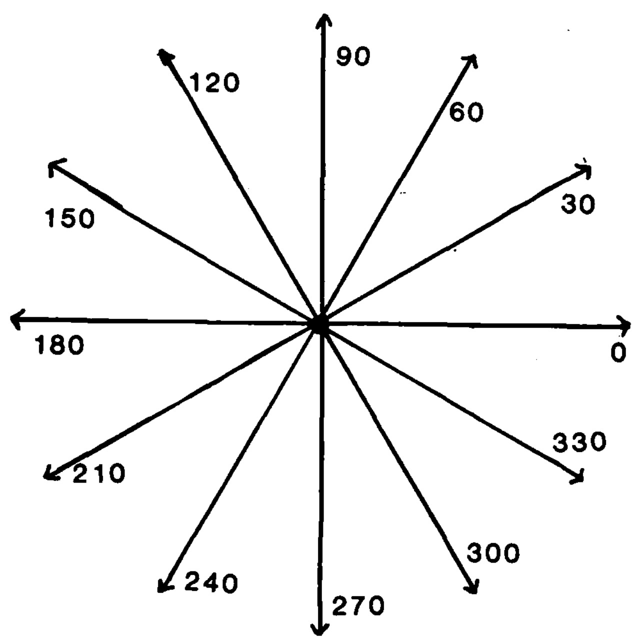


FIGURE L

SWEEP AT 60 DEGREES

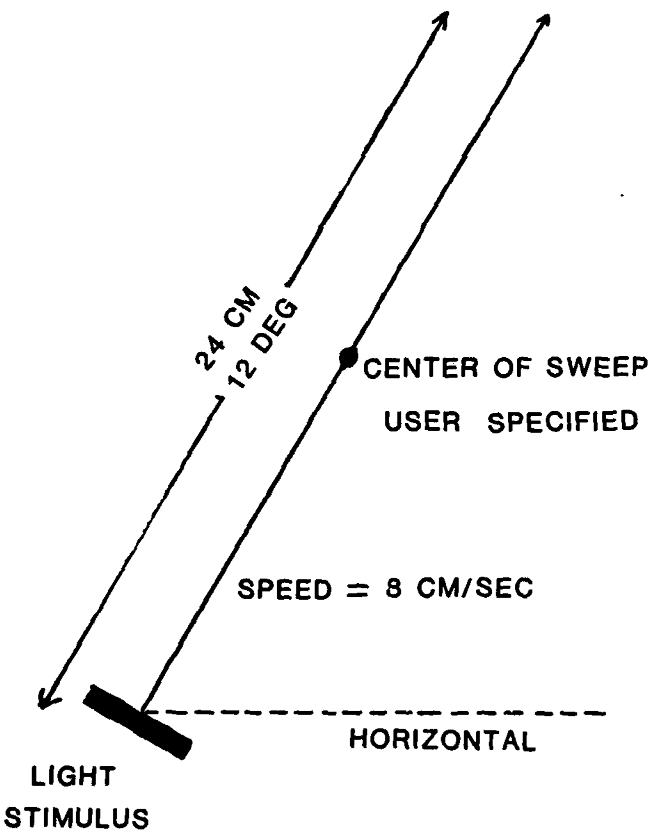


FIGURE N

DATA REPORT ORDER

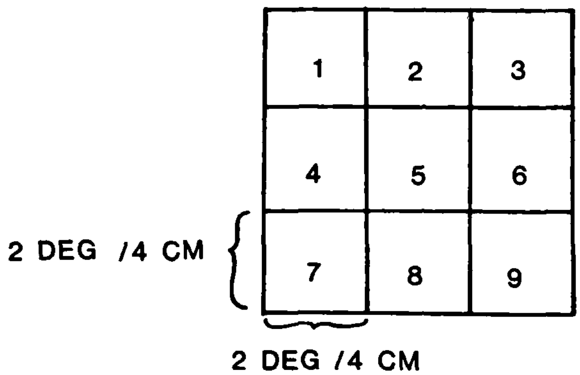


FIGURE M

RANDOM DATA COLLECTION ORDER

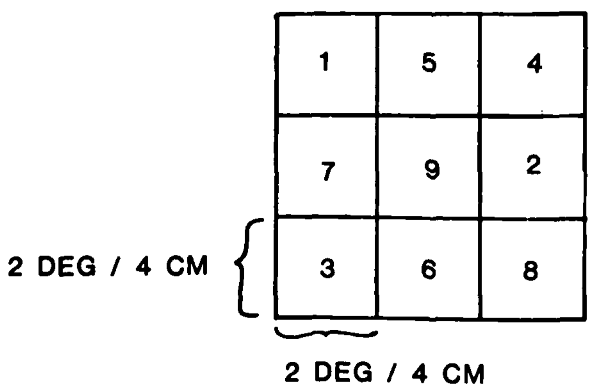


FIGURE O.

HORIZONTAL ANALOG SEARCH

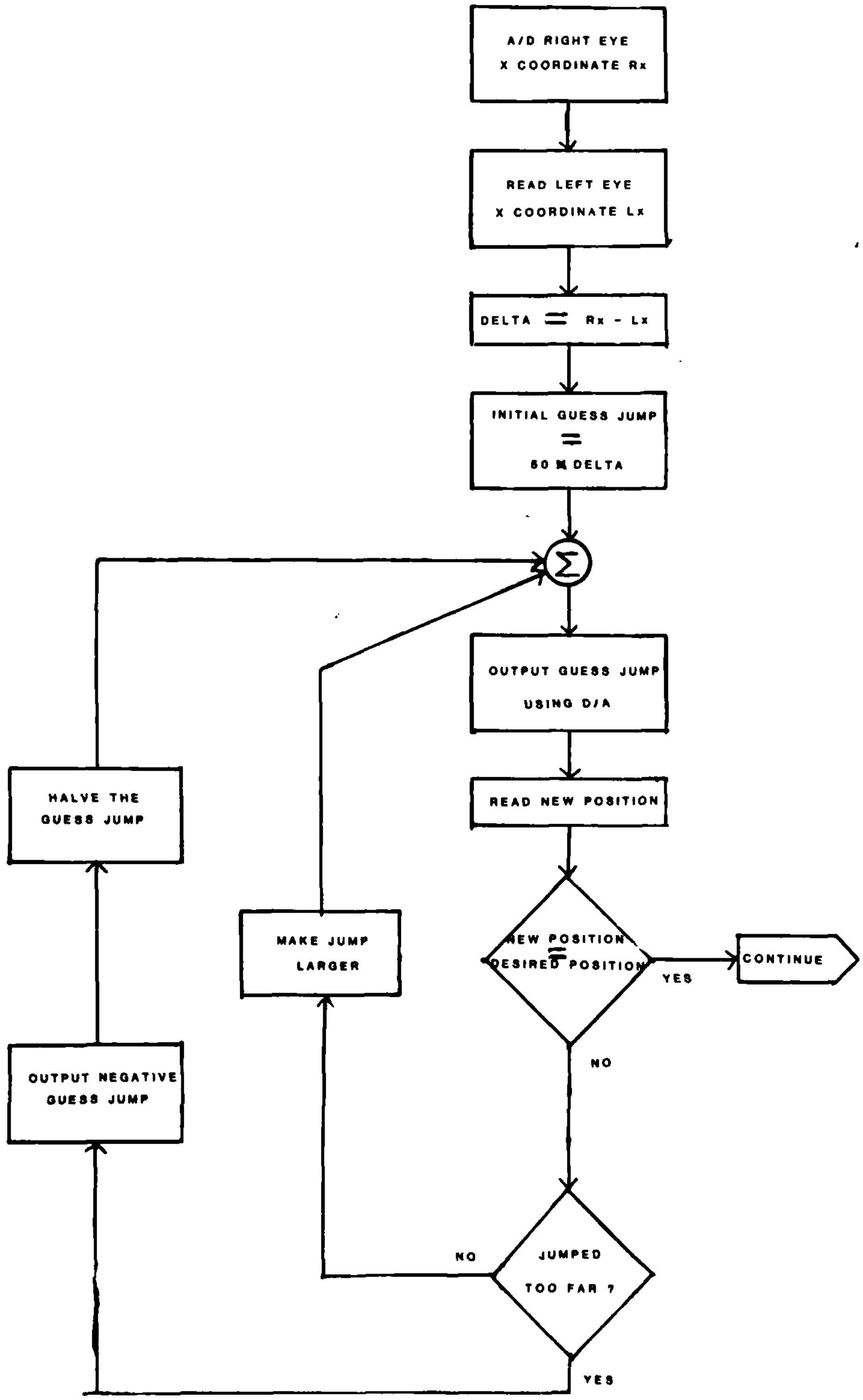
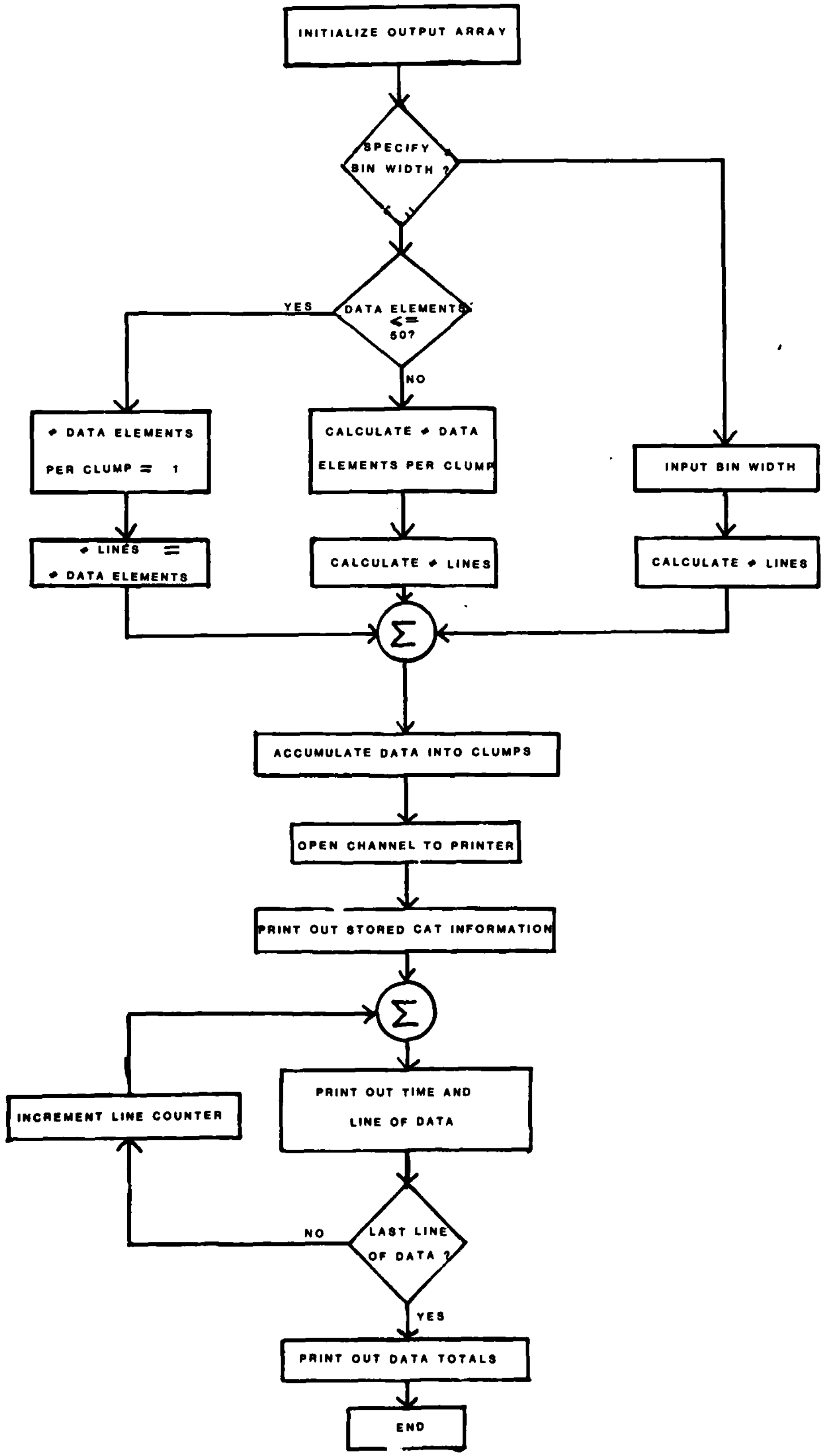


FIGURE P PRINTING DATA



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